Geophysical Research Abstracts, Vol. 8, 10284, 2006
SRef-ID: 1607-7962/gra/EGU06-A-10284

Calcite biomineralization in plant roots: an important process of secondary $CaCO_3$ accumulation in soils

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Rooted vascular plants play an important role in mineral weathering and element recycling in soils through a range of physical, chemical and biochemical processes. In calcareous soils, root-mediated processes can considerably affect the dissolution and reprecipitation of carbonate minerals through water uptake and respiration. Precipitation of secondary $CaCO_3$ is strongly enhanced by microbial communities in the root-soil system. Furthermore, significant accumulations of secondary soil carbonate are formed directly through biologically induced $CaCO_3$ mineralization in roots. This process appears to be a common phenomenon in modern soils and has also been reported in experimental work.

Products of $CaCO_3$ biomineralization (calcification) in plant roots reported here were studied in calcareous soils from Mediterranean environments of the Alicante region, SE Spain. The area is dominated by xerophytic shrub vegetation and is characterized by a seasonal moisture regime. Soils, developed over marl and limestone bedrock, are typically associated with accumulations of secondary soil carbonate. In the studied profiles, aggregates of calcified fine roots may locally represent more than a half of the soil mass.

The structure of living and dead calcified roots, analyzed by optical microscopy and SEM, shows that the precipitation of $CaCO_3$ occurs intracellularly in the cortex of fine roots. XRD and EDS analysis indicates that the cell-shaped crystals consist of a stoichiometric calcite or very low-Mg calcite. Calcified parts of the roots (1-2 mm in diameter) are generally thicker than non-calcified parts and are often composed of radially elongate calcified cells, indicating radial cell expansion which gave rise to a ’fat root’ appearance. Precipitation of $CaCO_3$ is limited to the cells of the cortical parenchyma, while the cells of the apical meristem, vascular cylinder and epidermis are not calcified.

Carbonate biomineralization in the root cortical cells, coupled with extrusion of protons, most probably represent an effective nutrient acquisition mechanism. Proton (acid) secretion in itself enables plants to mobilize sparingly soluble nutrients in the rhizosphere. Intracellular carbonate precipitation may, however, additionally increase production of protons which are potentially useful for nutrient assimilation in nutrient-poor calcareous soils. Simultaneously, accumulation of $CaCO_3$ in the root tissue might reflect protection of the plant from excessive calcium concentrations in the soil solutions.